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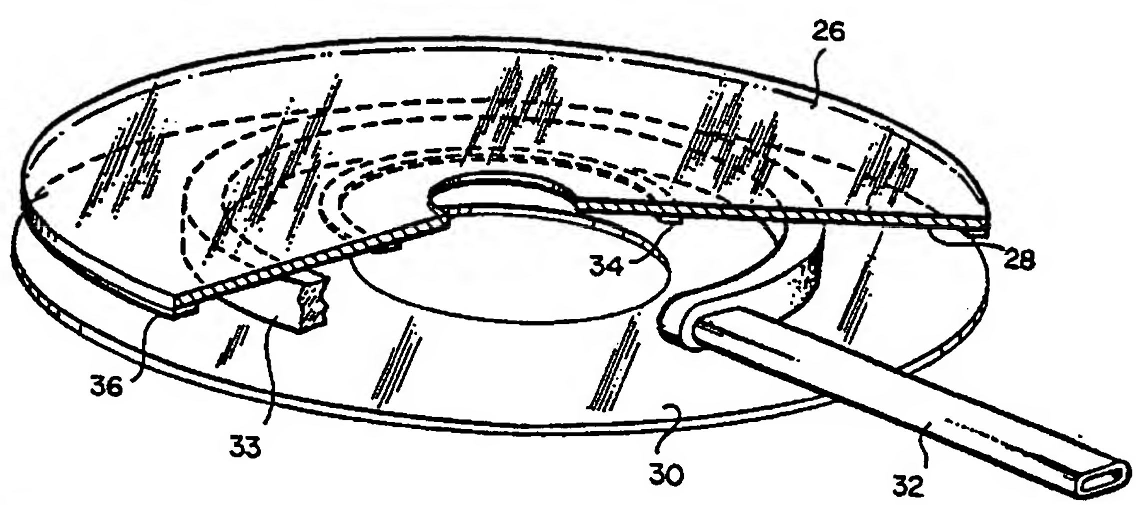
(54) Title: PROCESS FOR MAKING OPTICAL RECORDING MEDIA



(57) Abstract

A process for making an optical write-and-read recording disk medium by applying to a substantially flat disk substrate (30) a thin uniform layer of fluid composition between radially inner and outer boundary control rings (34 and 36) that repel the composition. A circular bead (33) of the composition is injected into a gap established between a surface of the disk substrate (30) and an opposing surface (28) of a master mold (26). The bead (33) is applied at a radius such that the surface area of the disk substrate (30) between the inner ring (34) and the radius is approximately equal to the surface area of the disk substrate (30) between the radius and the outer ring (36). The gap between the substrate (30) and the mold (26) is then closed such that the bead of composition spreads radially inwardly and outwardly from the radius to the inner and outer rings (34 and 36). The rings retard, and thereby equalize, non-uniform fronts of the advancing composition. Both rings (34 and 36) may be of silicone material screen-printed on the opposing surface (28) of the mold (26).

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DESCRIPTION

PROCESS FOR MAKING OPTICAL RECORDING MEDIA

Technical Field

The present invention relates generally to record media useful in optical writing and reading of high-density information, and more particularly to improved fabrication methods for optical disks.

Background Art

Currently preferred optical disk technology employs disk elements with spiral or concentric tracks of minute, optically detectable marks (usually on the order of 1 µm or less in size). One real-time mode of recording (writing) such marks is by scanning tracks on the disk with an equivalently small beam of radiation (e.g., from a laser), which is modulated "off" or "on" according to an electrical signal representative of the information to be written. Information is recovered (read) by scanning the tracks with a larger, but still very tightly focused, radiation (e.g., light) spot. The recovered information is in the form of a fluctuating electrical signal obtained from a photodetector that senses the read-out light reflected from the recorded disk.

Fig. 1 is a cross-sectional view of a portion of a typical prior-art optical write-and-read recording disk assembly 10. Each disk assembly has a transparent substrate 12 coated on one side with a primer layer 14 and a featured (i.e., having a pattern of depressions and/or protuberances) molded sub-layer 16. The ridges and grooves of this sublayer define the tracks along which the information is recorded. A thin, reflective metal mirror coating 18 is applied to molded sub-layer 16

so that information may be optically recorded onto, and read from, the disk assembly. The mirror coating is in turn coated with a protective layer 20.

In order to write and read information in the form of minute markings, optical systems of high numerical aperture are used to focus light to small spots. Such optical systems have extremely small depths of focus, and the proper positional relation between the optical system and the record surface of the optical disk assembly must be stringently maintained. Therefore, it is highly desirable that the optical disk assembly support surface underlying the record layer, e.g., the metal coating, be smooth and flat.

One approach to achieving requisite smoothness and flatness has been to start with a disk substrate and then apply thereto a surface-smoothing sub-layer by a known photopolymerization process, in which a liquid composition of acrylate monomers (esters of acrylic acid) is polymerized on a featured mold by exposure to ultraviolet radiation. Figs. 2a to 2d illustrate steps in that prior-art process. A few milliliters of the liquid composition (22 in Fig. 2a) are applied to the center of a metal master mold 24. A transparent substrate 12' is placed on the mold such that the space between the master mold and the substrate is filled by a layer of liquid composition 22. This layer is exposed to ultraviolet radiation (Fig. 2c) to polymerize the composition and form sub-layer 16'. The polymerized composition does not adhere to the mold but does adhere to the substrate; and after the exposure, the substrate and the cured sub-layer adhered thereto are removed from the master mold, as shown in Fig. 2d. A reflective metal

mirror coating 18 and protective layer 20 (Fig. 1) can then be applied to the sub-layer to complete the disk assembly.

In accordance with the prior art (as shown in U.S. Patent No. 4,395,211), the acrylic composition is centrally deposited on the surface of the master mold, and is spread over the master mold when a substrate is pressed against the composition. To inhibit inclusion of air bubbles in the composition, the flexible substrate may be spherosymmetrically vaulted before being pressed against the composition, whereby the composition is rolled out over the master mold surface while the vaulted substrate is deformed to a planar configuration. The liquid is then cured, and the substrate and attached cured acrylic composition are removed from the master mold.

The above-noted molding technique may be effective to inhibit air entrapment in the composition, but it requires that the substrate be flexible. It has, however, been discovered that rigid disks (made of, for example, aluminum) provide desirable characteristics when used as substrates for optical disk assemblies. See commonly assigned U.S. Patent No. 4,619,804. Preforming the substrate into a spherosymmetrically vaulted form is inappropriate for substrates of rigid material, and other means for inhibiting air entrapment are required.

Disclosure of Invention

The method of the present invention entails making an optical write-and-read recording disk medium by applying to a substantially flat disk substrate a thin uniform layer of fluid composition between radially inner and outer boundary control rings which repel the composition. A circular bead of the composition is

injected into a gap established between a surface of the disk substrate and an opposing surface of a master mold. The composition is applied at a radius such that the surface area of the disk substrate between the inner boundary control ring and the radius is approximately equal to the surface area of the disk substrate between the radius and the outer boundary control ring. The gap between the substrate and the mold is closed such that the fluid composition spreads radially inwardly and outwardly from the circular bead to the inner and outer boundary control rings, which slow the advance of non-uniform fronts of the composition and allow those fronts to equalize. In a preferred embodiment, the boundary control rings are made of silicone and are screen-printed on the operative surface of the master mold. Such rings also may act as reservoirs to accommodate any surplus composition.

The invention and its advantageous effects will become more apparent in the detailed description of the best mode presented below.

Brief Description of the Drawings

The following description of the best mode refers to the accompanying drawings, wherein:

Fig. 1 is a fragmental sectional view of an optical disk assembly in accordance with the prior art;

Figs. 2a-2d are a series of fragmental sectional views illustrating a prior-art process for making optical disk assemblies;

Fig. 3 is a perspective sectional view showing one step of a process for making single-sided optical disk assemblies in accordance with the present invention;

Fig. 4 is an enlarged, fragmental, perspective sectional view of mold structure depicted in Fig. 3; and

Fig. 5 is an exploded perspective view of apparatus partially shown in Fig. 3.

Among the figures described above, Fig. 3 best illustrates the basic features of this invention.

Best Mode for Carrying Out the Invention

The manufacturing method described herein presents a process for making optical disk assemblies by molding a radiation-curable plastic sub-layer onto a substrate disk. This process involves placing a clear glass master mold in spaced alignment with the substrate, injecting a viscous, radiation-curable, fluid composition between the master mold and the substrate disk, spreading the composition uniformly and without defect over the substrate disk, exposing the composition to radiation, and delaminating the master mold from the disk, leaving the sub-layer bonded to the disk. Metal and other layers may be coated over the sub-layer to complete the disk assembly.

Referring to Fig. 3, a master mold 26 consists of a flat glass plate. One surface (the bottom one in Fig. 3) 28 of master mold 26 has been ground and polished, preferably to a finish with defects no larger than about 10 to 15 Å RMS and scratches no wider than 0.0254 µm. The smooth surface may have data or formatting information etched therein. Details of a preferred method for manufacturing the master mold can be found in the aforementioned U.S. Patent No. 4,619,804.

The molding technique in accordance with the present invention is described with reference to Fig. 3. A master mold 26 is positioned opposite to a substrate disk 30 such that parallel surfaces of the master mold

and the substrate are closely spaced to form a uniform gap. A nozzle 32 extends into the gap to deliver a circular bead 33 of photopolymer between the master mold and the substrate. Details of the nozzle are set forth below with reference to Fig. 5. The circular bead is formed when the nozzle moves in a circular path within the gap. Of course the nozzle can be held stationary and the master mold and substrate rotated about their common axis.

With the correct gap, photopolymer pumping rate, and nozzle tip velecity, the photopolymer wets both the surface 28 of the master mold and the opposing surface of the substrate to form a uniform annular column 33 suspended between the master mold and substrate surfaces due to capillary action. Suspension of the column allows the bead of photopolymer to cling to both surfaces while it is fluid, thus inhibiting any trapping of small air bubbles in the photopolymer between the two surfaces. Experiments with a photopolymer whose viscosity is in the 100–150 cp range, having contact angles with the substrate and master mold of about 25^{o} to 40^{o}, indicate that the column can be reliably established and maintained if the separation between the master mold and substrate surfaces is less than about 0.25 cm. For best results, the ratio of the nozzle tip velocity in centimeters per second to the photopolymer delivery rate in cubic centimeters per second should not exceed about 31 to 1.

The photopolymer column is formed at a radius such that the surface area between a predetermined inside diameter to which the photopolymer is to be spread and the photopolymer column is approximately equal to the surface area from the photopolymer column outwardly to

an outside diameter to which the photopolymer is to be spread. Spacer rings 34 and 36 have been provided at those inside and outside diameters.

Delivery of the photopolymer along nozzle 32 may be effected by any suitable mechanism. The presently preferred method is to provide a syringe driver, not shown, to meter a precise volume of photopolymer at a flow rate synchronized with the angular velocity of the nozzle relative to the master mold and substrate.

When the annular photopolymer column has been established, the nozzle is withdrawn. The gap is then closed, forcing the photopolymer column to be flattened such that the photopolymer composition spreads radially inwardly and outwardly from the column to form a uniform, defect-free film. As the photopolymer composition spreads toward the inside and outside diameters, it conforms to minute surface features of both the substrate and the master mold. Boundary control rings 34 and 36 inhibit photopolymer composition runoff at the inside and outside diameters, provide a uniform gap, and act as reservoirs to accommodate any surplus composition.

Boundary control rings 34 and 36 (an enlarged detail of ring 36 is shown in Fig. 4) preferably are screen-printed onto the master mold surface 28. The ring material is selected so as to inhibit composition spread by repelling the composition in a manner similar to the way wax repels water. Silicone is a suitable material for such rings.

Rings 34 and 36 are patterned to allow any air pushed ahead of each composition front to escape while restricting passage of the composition itself. By repelling the composition, the rings retard outermost

portions of each front while lagging portions catch up, thereby tending to keep both fronts circular as they approach the rings. The composition is thus more evenly distributed over the substrate, and runoff of the composition beyond rings 34 and 36 is prevented.

The film is polymerized by exposure to ultraviolet radiation through transparent master mold 26. The radiation source may be a mercury-vapor lamp having a wave length of about 330 nm to 450 nm.

The photopolymer composition is formulated to preferably adhere to substrate 30 and become a highly cross-linked solid replicate of the master mold's surface. Upon separation of the master mold from the substrate, the photopolymer does adhere slightly to the master mold, thereby removing any dirt particles which may be present, leaving the master mold clean for the next molding operation. The operation is thus self-cleaning.

The operation described above and shown in Fig. 3 produces a substrate having one side coated for production of a single-sided optical disk assembly. In commonly assigned copending International Application No. PCT/US86/ filed concurrently herewith (based on U.S. Serial No. 799,223, filed 18 November 1985), we have shown a similar operation, but wherein the substrate is being coated on two sides. The present invention is adaptable to double-sided disk manufacture in accordance with the process described in that copending application.

Fig. 5 shows details of a preferred embodiment of nozzle 32. The nozzle has a seamless, thin-wall, stainless-steel tube 38 attached, by flexible tube 39, to a photopolymer composition delivery system (not shown).

Tube 38 is elliptical in cross section, with its major and minor axes oriented during delivery such that the minor axis is in the direction of the gap width. Formation of a photopolymer composition column is aided by the presence of means for causing the composition stream to part as it leaves the nozzle and for causing a portion of the stream to be directed toward the substrate and another portion to be directed toward the master mold. A thin wire 40 across the nozzle tip directs composition exiting from the tip both upwardly and downwardly across the gap between the substrate and the master mold, whereby contact is made with the opposing surfaces thereof to permit capillary action to form the column. Thin wire 40 also allows withdrawal of the nozzle tip from the composition column without causing composition to trail behind the tip.

This invention has just been described in detail with particular reference to the best mode and preferred embodiments contemplated for carrying it out, but it will be understood that variations and modifications thereof can be effected within the spirit and scope of the invention claimed.

CLAIMS

1. A method for making an optical write-and-read medium by applying a layer of fluid composition to a flat face of a substrate member (30), said layer of composition being curable to a solid and having a uniform thickness covering a predetermined annular area of said substrate member (30), said method comprising the steps of:

providing on a flat face (28) of a master mold member (26) radially inner and outer boundary control rings (34 and 36) concentrically disposed with an annular space therebetween, to define respective inner and outer limits of said predetermined annular area of said substrate member (30), said rings (34 and 36) being made of a material that repels said composition;

positioning said substrate member (30) and said master mold member (26) so that said flat faces thereof are in confronting relation to each other but separated by a distance providing a gap between said rings (34 and 36) on said mold member (26) and said flat face of said substrate member (30);

providing in said annular space between said rings (34 and 36) an annular column (33) of said composition having a selected volume defined by said uniform thickness and said predetermined annular area, said column (33) being disposed between and in wetting contact with said confronting flat faces of said substrate and mold members (30 and 26); and

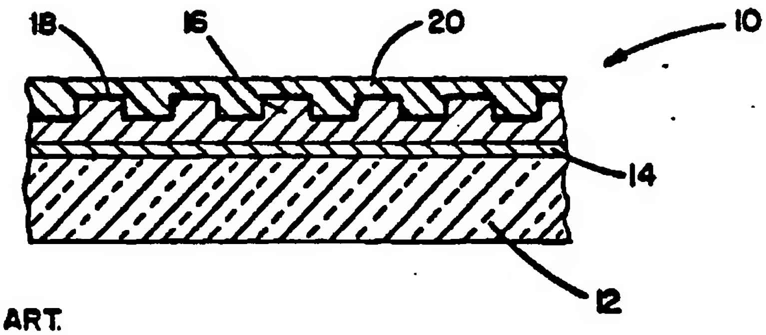
reducing said distance between said confronting faces of said members (30 and 26) to a dimension corresponding to said uniform thickness, so as to bring

said flat face of said substrate member (30) into contact with said rings (34 and 36) on said mold member (26) and thereby form an annular cavity bounded by said faces and said rings (34 and 36) while causing said column (33) to be displaced radially to fill said cavity, whereby a substantially defect-free layer of said composition having said uniform thickness is established between said faces and covering only said predetermined annular area of said substrate member (30).

2. A method as claimed in Claim 1 wherein said step of providing said boundary control rings (34 and 36) includes printing a silicone material on said flat face (28) of said master mold member (26).

3. A method as claimed in Claim 2 wherein said printing includes providing said material with a pattern that renders said rings (34 and 36) air-permeable, whereby air pushed ahead of said radially displaced column can escape through said rings (34 and 36).

4. A method as claimed in Claim 1 wherein said step of providing said column (33) of said composition includes disposing said column (33) concentrically between said rings (34 and 36) so that resulting annular areas between said column (33) and said rings (34 and 36) are substantially equal.



PRIOR ART

FIG. 1

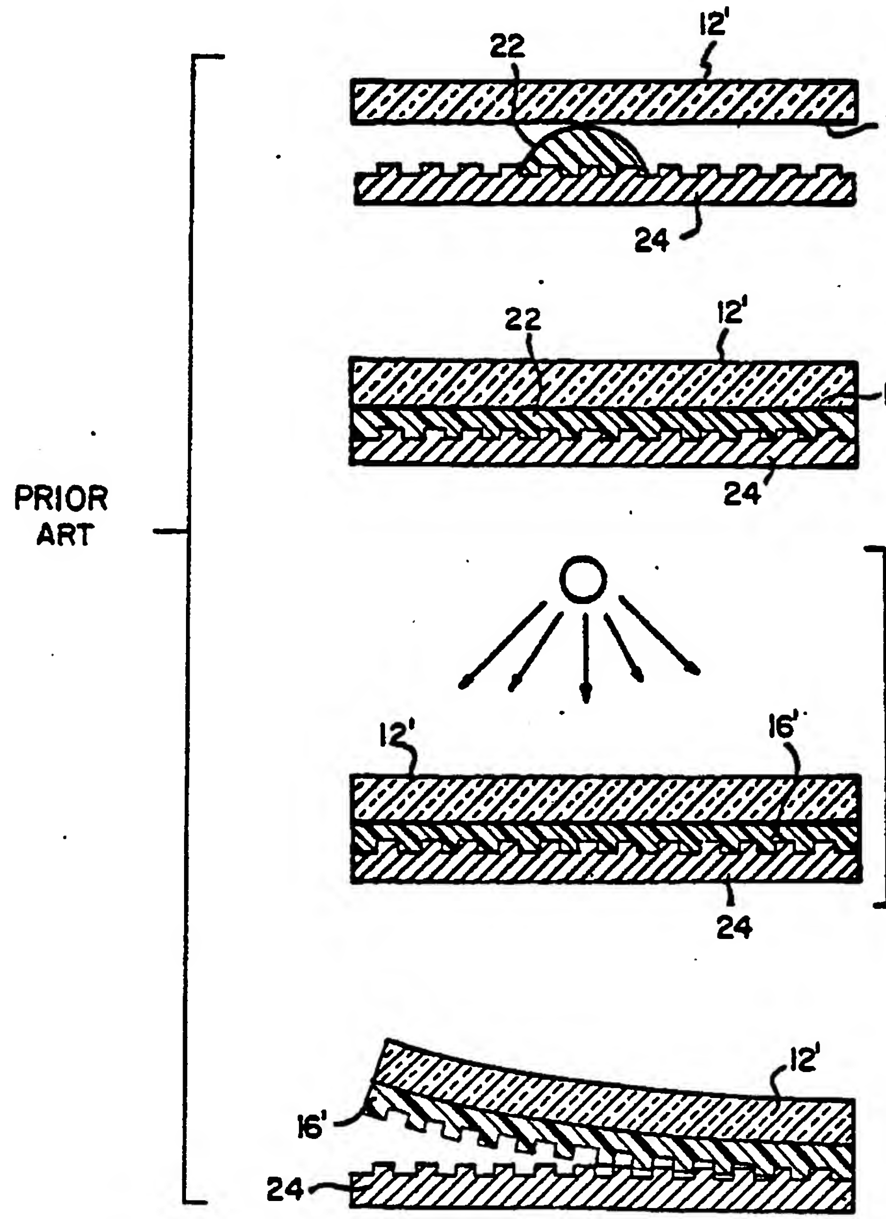


FIG. 2a

FIG. 2b

FIG. 2c

FIG. 2d

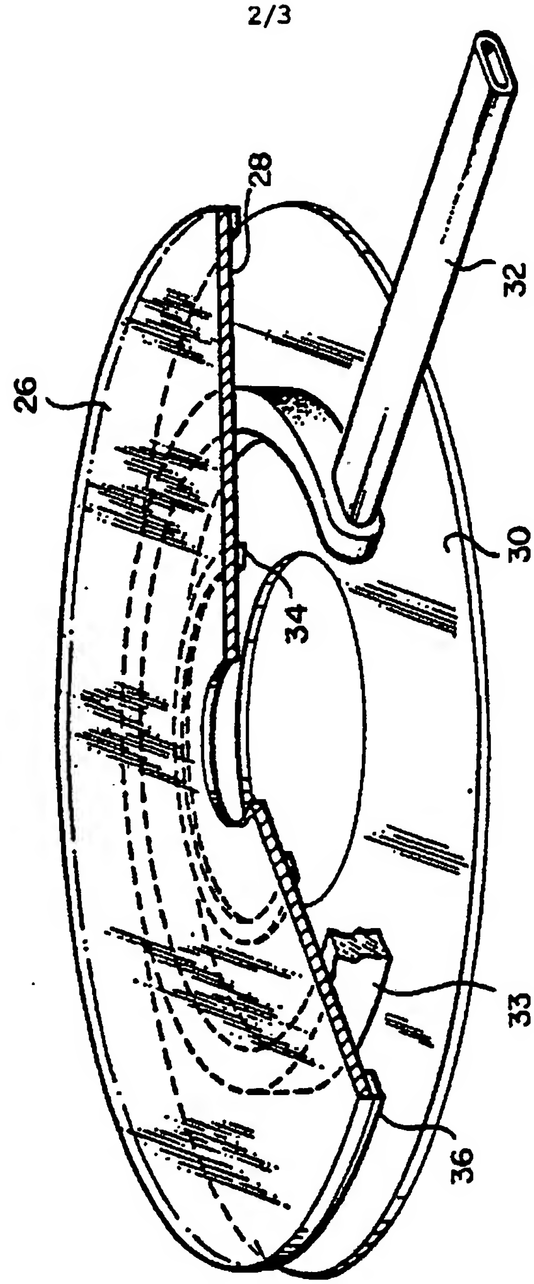


FIG. 3

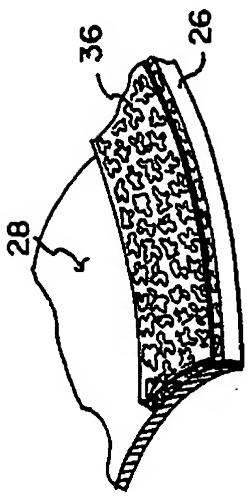


FIG. 4

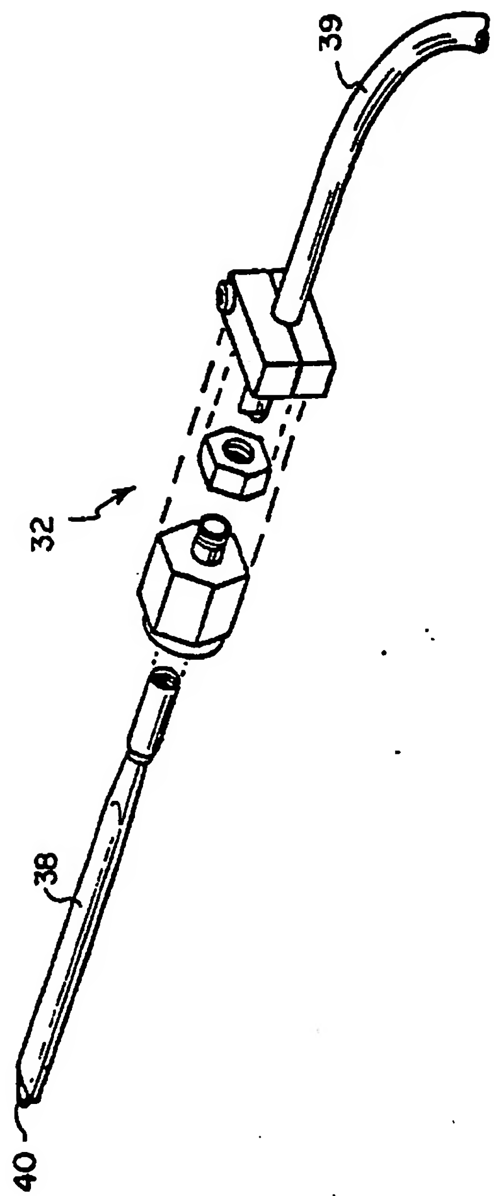


FIG. 5

INTERNATIONAL SEARCH REPORT

International Application No PCT/US 86/02384

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [8]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC^4: B 29 D 17/00; B 29 C 43/34; B 29 C 33/00

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC^4	B 29 C; B 29 D; G 11 B

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
Y	US, A, 2499397 (G.A. LYON) 7 March 1950, see the whole document --	1,4
Y	US, A, 1500698 (A. WIEHL) 8 July 1924, see page 2, lines 80-117; figures 5,6,7 --	1,4
Y	FR, A, 1316239 (GEBRÜDER BATTENFELD) 17 December 1962, see page 1, lines 1-49; page 2, lines 96-102; figures 4,5 --	1,4
A	GB, A, 0664730 (PIRELLI) 9 January 1952, see the whole document --	3
A	US, A, 3485908 (E.M. BURGER) 23 December 1969, see the whole document --	1,3,4
A	EP, A, 0079262 (THOMSON-CSF) 18 May 1983, see the whole document --	1,2
A	US, A, 4257988 (R.J. MATOS) 24 March 1981, see figures 2,3 ----------	1

* Special categories of cited documents: [10]

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
22nd January 1987	27 MAR 1987
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	M. VAN MOL

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON

INTERNATIONAL APPLICATION NO. PCT/US 86/02384 (SA 15190)

This Annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on 02/02/87

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Patent document cited in search report	Publication date	Patent family member(s)		Publication date
US-A- 2499397		None		
US-A- 1500698		None		
FR-A- 1316239		None		
GB-A- 664730		None		
US-A- 3485908	23/12/69	None		
EP-A- 0079262	18/05/83	FR-A,B	2516286	13/05/83
		JP-A-	58084731	20/05/83
		US-A-	4452748	05/06/84
		CA-A-	1197006	19/11/85
US-A- 4257988	24/03/81	None		

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